

**The Impact of Foot-and-Mouth Disease (FMD)
on Hog, Pork, and Beef Prices:
the Experience in Korea**

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The Impact of Foot-and-Mouth Disease (FMD) on Hog, Pork, and Beef Prices: the Experience in Korea

Practitioner's Abstract

Korea experienced two outbreaks of foot-and-mouth disease (FMD), one in the year 2000 and one in 2002. After the first outbreak, prices for hogs, pork, and beef dropped 15-20% before the government began an intervention program. The effects of these two outbreaks are examined using Box and Tiao's intervention analysis model and a GARCH model. Although the second outbreak resulted in many times more animal deaths than the first outbreak, its effect on prices was much smaller. The reason may be because the government's response to the first outbreak set a precedent for the second one.

Keywords: *Foot-and-mouth disease (FMD), Korea, ARIMA, GARCH, Box-Tiao intervention analysis*

Introduction

Foot-and-mouth disease (FMD) is a virus that attacks cloven-hoofed animals such as pigs, cattle, sheep, and goats. The economic impacts are potentially debilitating, with predicted damage in California alone running into the billions of dollars (Ekboir). Fortunately, studies focusing on impacts in the U.S. have been only predictions, but outbreaks have actually occurred in other countries, including the U.K. and Korea. Most estimates of the impacts of FMD in these countries have focused on the livestock, tourism, and related industries using input-output analysis, partial and/or general equilibrium model, and benefit and cost analysis for the control of epidemic diseases (see Aulaqi and Sundquist; Blake, Sinclair, and Sugiyarto; Fuller, Fabiosa, and Premakur; Paarlberg, Lee, and Seitzinger, 2003; Petry, Paarlberg, and Lee; and Paarlberg, Lee, and Seitzinger, 2005).

This paper, however, focuses on the short-term price impacts resulting from two outbreaks in Korea. The outbreaks decreased both domestic and foreign demand for Korean pork. Upon news of the first outbreak, hog farmers immediately increased their sales of hogs since they expected FMD to decrease the price of pork. In addition, Japan halted all imports from Korea. The rapid drop in hog prices, in addition to decreased quantity of pork sold, caused significant financial loss. To prevent further loss, the government launched an emergency program to support hog prices by purchasing all pork affected by FMD-related embargoes, setting a precedent for further outbreaks.

Our paper attempts to investigate the reactions of hog and cattle markets to two FMD shocks that occurred in Korea in March 2000 and May 2002 by modeling prices of hogs, pork, and beef in an Intervention Analysis. We seek to:

- a) examine whether Box and Tiao's or a GARCH intervention model can best explain the behavior of hog, pork, and beef prices after each of the two FMD shocks, and
- b) compare how these markets reacted to each of the two outbreaks.

The Outbreaks

According to the Korean government, the first outbreak occurred when 15 animals in a dairy herd in KyoungGi PaJu were infected on March 20, 2000. The infections were reported on March 26, 2000, and officially diagnosed April 2, 2000. One hundred six animals in that herd were destroyed. Over the next 26 days infections in 15 more beef and dairy herds were discovered, and 2,223 pigs, cattle, sheep and goats from 182 farms within a radius of 500 meters of these infected herds were destroyed.

The government began its intervention on March 29, 2000, four days before the official diagnosis of FMD was made. This intervention included destroying all susceptible animals in the infected farm and adjacent farms, and disinfecting those farms. A protection zone with a 10 km radius was set up around the infected farms, prohibiting movement of susceptible animals and semen. Emergency vaccination was conducted within this zone.

A surveillance zone with a 20 km radius was set up, which prohibited movement of susceptible animals as well as livestock markets. Outside of the protection and surveillance zones, intensive surveillance, including serological testing (10,014 animals were tested) and clinical investigation, was conducted. Also, in addition to ante-mortem inspection, post-mortem inspection was implemented at slaughterhouses.

In an attempt to stabilize prices, the government purchased, through a major cooperative, 6,000 animals per day, paying \$143/head for hogs designated for export, and \$166/head for hogs in the surveillance zones. The government spent a total of \$300 million for this purchase program, sterilization and vaccination, payment for slaughter fees, and support for farm households.

With this intervention, the government established a precedent based on concentric circles around an infection site. Within a radius of 2-3 km, all animals would be slaughtered and buried and government would pay producers estimated cost of production. Within a 20-km radius, all animals would be slaughtered, butchered, and meat placed into refrigerated storage for later resale if certified safe, and government would pay producers the previous market price. For the entire country, government would pay producers previous market price.

Table 1. Animals Infected/Destroyed in Two Outbreaks

	2000 Outbreak	2002 Outbreak
Animals Infected	94	439
Animals Destroyed	2,223	160,145

Source: Korean Government

Model Specification and Estimation

The first model considered is Box & Tiao's Simple Intervention Analysis (SIA) Model, which can be written as

$$\nabla^d Y_t = \xi + \sum_{i=1}^p \omega \nabla^d B^i I^{(T)}_i + \nabla^{-f} \frac{\theta(B)}{\phi(B)} a_t \quad (1)$$

where ξ is the constant term, d is the differencing parameter, $\nabla = 1 - B$, $\theta(B) = 1 - \theta_1 B - \dots - \theta_q B^q$, $\phi(B) = 1 - \phi_1 B - \dots - \phi_p B^p$, B is the backshift operator on t , and f is a fractional differencing

parameter, $f = 0$. I_t^T is the intervention series, ω is the parameter indicating the magnitude of the intervention and $\nabla^{-f} \frac{\mathcal{G}(B)}{\varphi(B)} a_t$ is the stationary error component. In this paper two types of intervention series are used: a pulse (P_t^T) series that reflects influence at a certain time; and a step (S_t^T) series that reflects continuous influence from a point in time, denoted respectively by,

$$I_t^T = P_t^T = \begin{cases} 0, & t \neq T \\ 1, & t = T \end{cases} \quad I_t^T = S_t^T = \begin{cases} 0, & t < T \\ 1, & t \geq T \end{cases} \quad (2)$$

In practice, two of the most common models for the error are the AR(p) and IMA(q) which correspond respectively to $p = p, d = 0, \text{ and } q = 0$; and $p = 0, d = 1, \text{ and } q = q$. In the case of a step intervention, the SIA model implies that for $t \geq T + b$ an increase of ω occurred.

Depending on the parameters, Box & Tiao identify several forms that the intervention can take, including both pulse and step influences:

$$\begin{aligned} \text{(a)} \quad \omega B S_t^T & \quad \text{(b)} \quad \frac{\omega B}{1 - \delta B} P_t^T \\ \text{(c)} \quad \frac{\omega B}{1 - \delta B} S_t^T & \quad \text{(d)} \quad \left[\frac{\omega_0}{1 - \delta B} + \frac{\omega_1}{1 - B} \right] B P_t^T \\ \text{(e)} \quad \frac{\omega B}{1 - B} S_t^T & \quad \text{(f)} \quad \left[\omega_0 + \frac{\omega_1 B}{1 - \delta B} + \frac{\omega_2 B}{1 - B} \right] P_t^T \end{aligned} \quad (3)$$

These forms can be illustrated in the following figures:

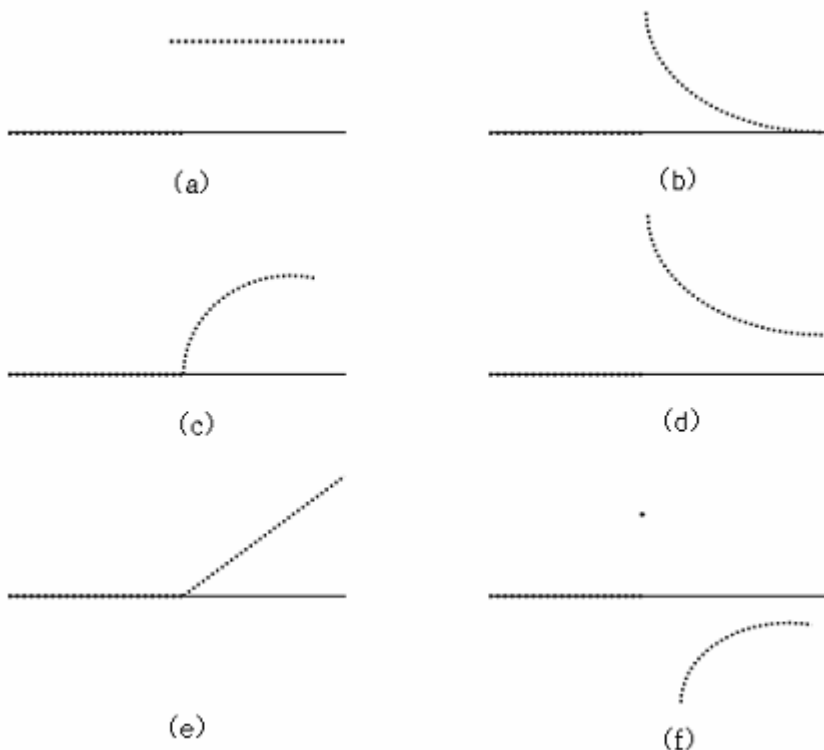


Figure 1. Types of Box-Tiao Interventions

Data Characteristics

The time series data used in the study are daily average spot prices of hogs expressed in Korean won per kilogram transformed from won per 100 kilograms prices released by the National Agricultural Cooperative Federation (NACF) and average auction prices in won per kilogram announced by the agricultural and marinary wholesale market operated in Seoul. The data represent prices from January 4, 1999 to December 31, 2003. Spot prices of beef are not used since the spot market was closed from April 5, 2000 to May 20, 2000 and from May 14, 2002 to July 9, 2002 because of the FMD outbreaks.

Table 2. Statistical Summary of Data

Year	Hog price (Won/Kg)		Wholesale Pork price (Won/Kg)		Wholesale Beef price (Won/Kg)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1999	1,988.4	161.6	2,991.8	303.5	9,051.9	1,423
2000	1,693.0	311.8	2,351.5	504.8	9,746.7	803
2001	1,745.2	218.3	2,377.3	307.7	11,748.0	2,376
2002	1,769.8	273.0	2,371.5	400.2	13,334.0	1,453
2003	1,645.2	206.1	2,117.6	260.6	14,331.0	911
Average	1,769.6	267.6	2,445.2	467.4	11,623.0	2,514

Table 1 indicates that the average hog and wholesale pork prices for 2000, the year of the first FMD outbreak, are lower than in other years and the volatilities are higher. However, the same is not apparent for wholesale beef prices in 2000 or for any of the prices in 2002, the year of the second outbreak.

Figure 2 shows daily prices for hog, pork, and beef prices in Korea from 1999 through 2000, with the date of the first FMD outbreak highlighted. Figure 3 provides a closer perspective of prices immediately before and after the date of the FMD outbreak.¹

¹ Although prices from 11/12/1999 and 7/6/2000 appear to be outliers, inconsistent data sources made it difficult to verify this. Models were estimated using these data points, and then replacing these data points with values generated using a moving average, but results differed little.

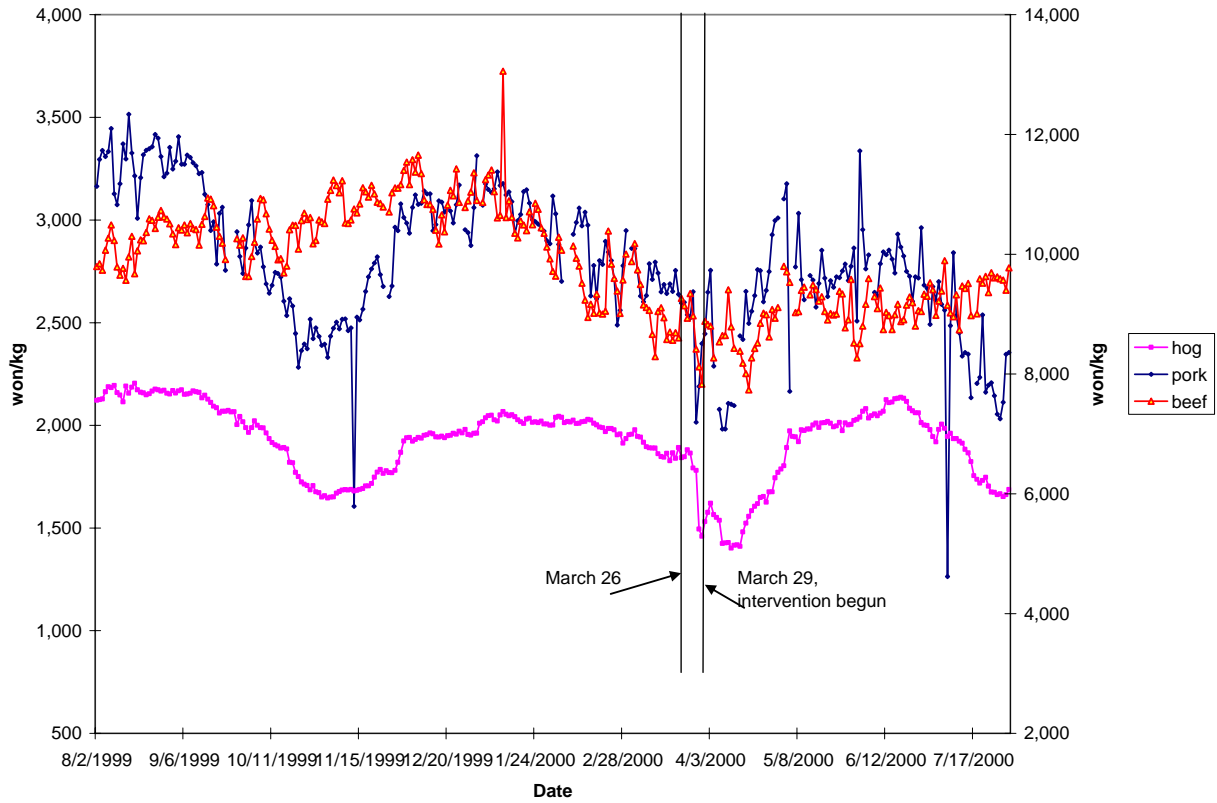


Figure 2. Price Series for Hogs, Pork, and Beef in Korea, October 10, 1999 – December 13, 2000

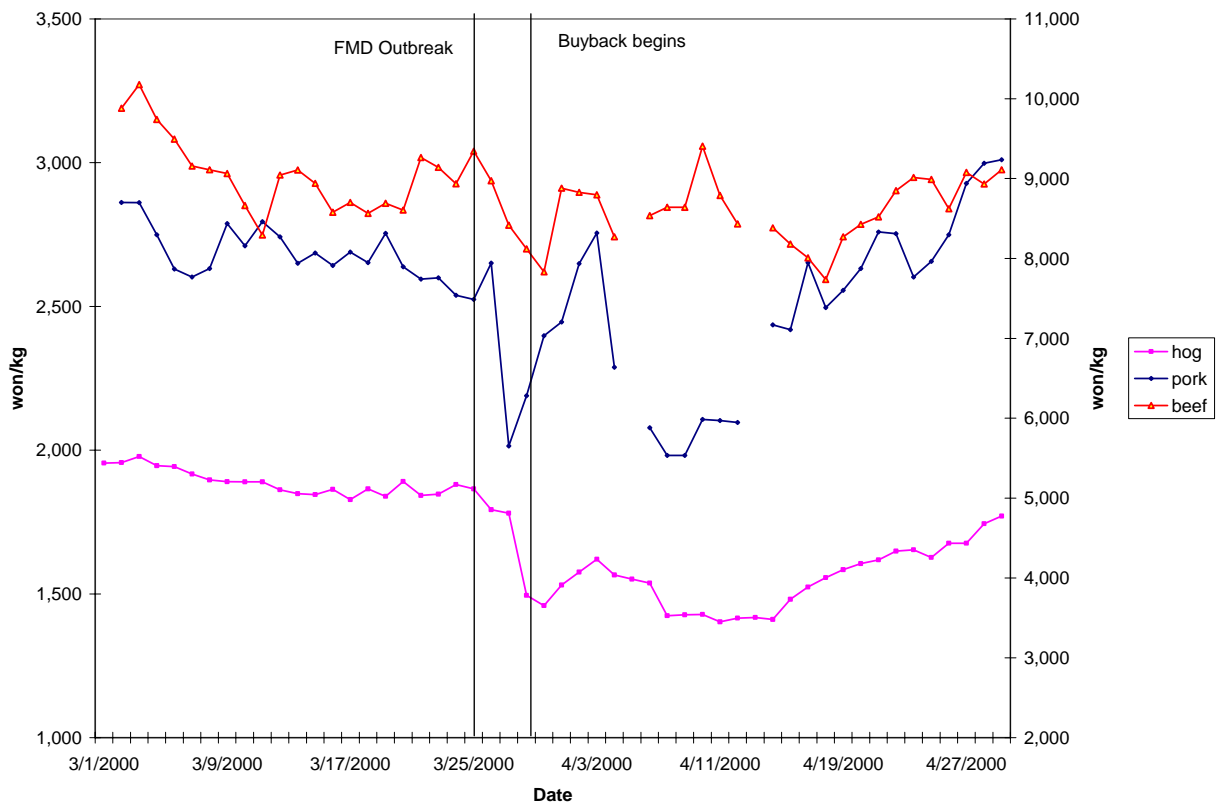


Figure 3. Price Series for Hogs, Pork, and Beef in Korea, January 12, 2000 – April 28, 2000

In contrast, Figure 4 shows daily prices for hog, pork, and beef prices in Korea during 2002, with the date of the second FMD outbreak highlighted. Figure 5 provides a closer perspective of prices immediately before and after the date of the second FMD outbreak. The figures suggest that, even though the second outbreak was much more severe in terms of animals killed, it had much less effect on market prices than the first outbreak did.

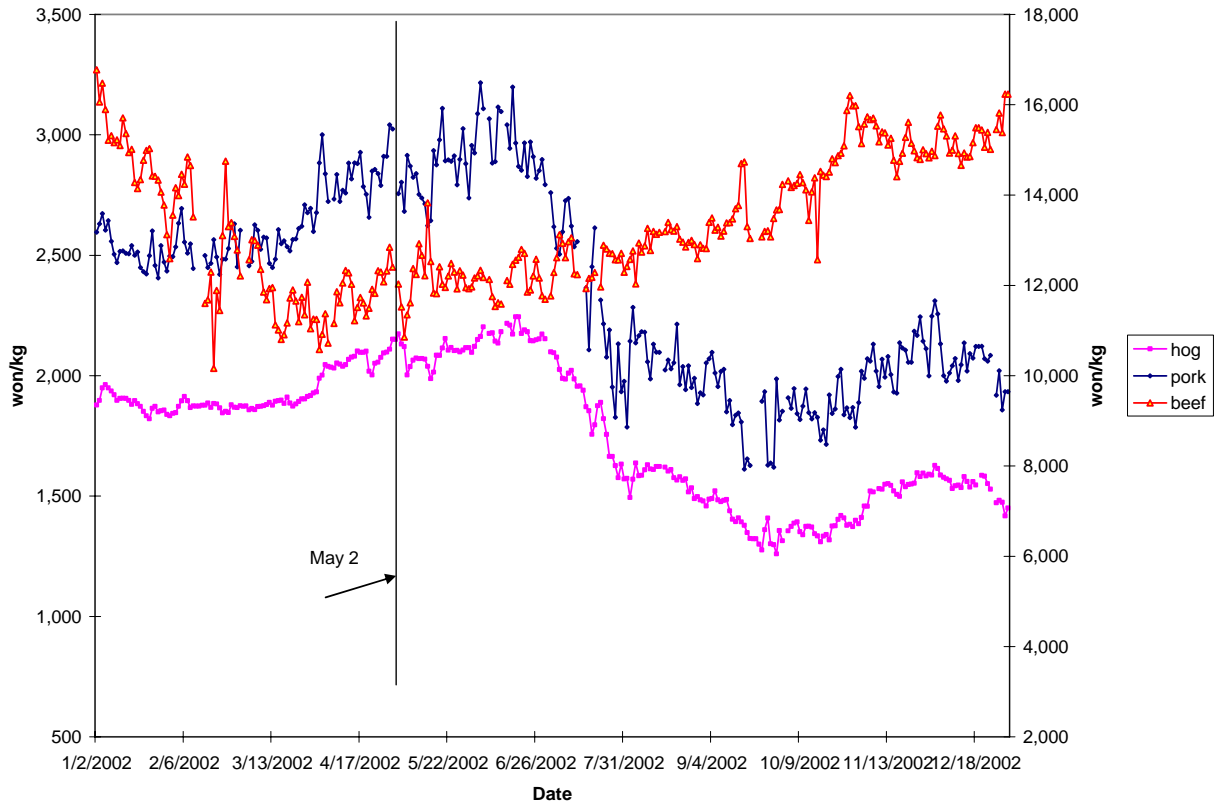


Figure 4. Price Series for Hogs, Pork, and Beef in Korea, 2002

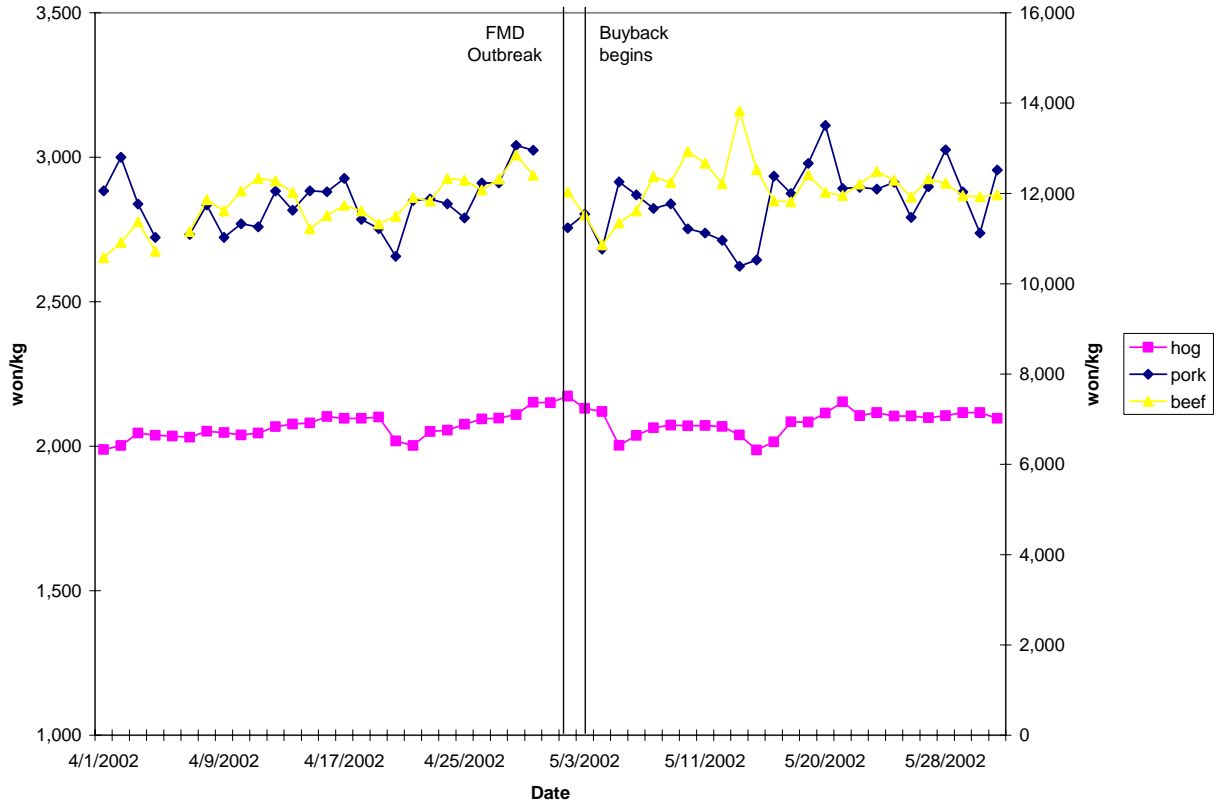


Figure 5. Price Series for Hogs, Pork, and Beef in Korea, April-May 2002

Estimation of the Box & Tiao SIM

The Phillips-Perron unit root test of the logarithmic price series failed to reject a hypothesis of unit roots, but rejected that hypothesis for first differenced logarithm of prices (Table 2).

Table 3. Results of Philips-Perron Unit Root Test

	Ln Y_t	Ln ΔY_t
Hog price	-2.42	-34.69**
Pork wholesale price	-2.98	-58.75**
Beef wholesale price	-2.30	-57.80**

** reject the null hypothesis at 1% significance level

The Box and Tiao SIA (Expression 1) was estimated in SAS using maximum likelihood criteria. A detailed discussion of this can be found in Box and Tiao. Once the model parameters were estimated, the adequacy of the fitted model was investigated by diagnostic checks of the residuals. The estimation results are presented in Table 4.

$$\Delta \ln Y_t = \alpha_0 + \sum_{j=1}^p \alpha_j \cdot \Delta \ln Y_{t-j} + \sum_{j=0}^q \beta_j \varepsilon_{t-j} + \left[\frac{\omega_0 B}{1 - \delta B} + \frac{\omega_1 B}{1 - B} \right] C_t^T + \frac{\psi_0 B}{1 - \gamma B} D_t^T \quad (4)$$

where $Y_t = (Y_{t1} Y_{t2} Y_{t3})'$, $\varepsilon_t = (\varepsilon_{t1} \varepsilon_{t2} \varepsilon_{t3})'$, with 1 representing hog prices, 2 representing wholesale pork prices, and 3 representing wholesale beef prices.

$$C_t^T = \begin{cases} 0, & t \neq 2000.04.05 \\ 1, & t = 2000.04.05 \end{cases} : \text{First FMD Outbreak Dummy,}$$

$$D_t^T = \begin{cases} 0, & t < 2002.05.14, t > 2002.07.07 \\ 1, & 2002.05.14 \leq t \leq 2002.07.07 \end{cases} : \text{Second FMD Outbreak Dummy}$$

$$\alpha_i = (\alpha_{i1} \alpha_{i2} \alpha_{i3})', \quad \beta_j = (\beta_{j1} \beta_{j2} \beta_{j3})', \quad \beta_0 = (1 \ 1 \ 1)',$$

$$\omega_i = (\omega_{i1} \omega_{i2} \omega_{i3})', \quad \delta = (\delta_1 \delta_2 \delta_3)',$$

$$\psi_j = (\psi_{j1} \psi_{j2} \psi_{j3})', \quad \gamma = (\gamma_1 \gamma_2 \gamma_3)',$$

Table 4. Estimation Results of the Box and Tiao SIM

		Hogs		Wholesale Pork		Wholesale Beef	
	Parameter	Coeff.	Parameter	Coeff.	Parameter	Coeff.	
AR	α_{01}	0.0002409 (0.34)	α_{02}	0.0002117 (0.37)	α_{03}	0.0004145 (1.32)	
AR	α_{11}	0.94570** (28.68)	α_{12}	-0.99861** (-43.16)	α_{13}	0.36835** (9.34)	
AR	α_{21}	-----	α_{22}	-----	α_{23}	0.10612** (3.30)	
MA	β_{11}	0.90974** (21.73)	β_{12}	-0.53397** (-7.74)	β_{13}	0.84083** (29.14)	
MA	β_{21}	-----	β_{22}	0.61348** (13.19)	β_{23}	-----	
MA	β_{31}	-----	β_{32}	0.14746** (4.98)	β_{33}	-----	
1st FMD	ω_{01}	-0.05859** (-4.44)	ω_{02}	0.02483** (3.51)	ω_{03}	-0.04391 (-1.22)	
1 st FMD	δ_1	0.78562** (10.65)	δ_2	-0.99888** (-1089.3)	δ_3	0.43830 (0.87)	
2nd FMD	ψ_{01}	-0.004334 (-1.53)	ψ_{02}	-0.0002013 (-1.36)	ψ_{03}	0.0002126 (0.02)	
2nd FMD	γ_1	-0.99393** (-157.31)	γ_2	0.97954** (53.71)	γ_3	0.45283 (0.02)	

():t-value, * : 10% significance level ** : 5% significance level

The orders of the SIM for the hog price, pork wholesale price, and beef wholesale price series are specified as ARIMA(1,1,1), ARIMA(1,1,3), ARIMA(2,1,1) based on diagnostic tests using Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC). The estimation results indicate that the impact type of the first FMD outbreak is of form (d) and that of the second FMD outbreak is of form (c) in Figure 1.

Generalized Auto-Regressive Conditional Heteroskedasticity (GARCH) Estimation

Bollerslev's GARCH model can be considered as an alternative for Box & Tiao's SIM when the error term of the ARIMA model is heteroskedastic, violating the white noise assumption. Lung-Box's Q-test and Engel's Lagrange Multiplier (LM) test are used to determine whether the price series are autocorrelated or characterized by autoregressive conditional heteroskedasticity (ARCH).

An autoregressive model with order p, AR(p), is estimated. The order p is determined using AIC and SBC (Schwartz Bayesian Criterion) model selection criteria.

$$\Delta \ln Y_{it} = \alpha_0 + \alpha_{1i} \cdot \Delta \ln Y_{it-1} + \alpha_{2i} \cdot \Delta \ln Y_{it-2} + \dots + \alpha_{ri} \cdot \Delta \ln Y_{it-p} + \varepsilon_t, \text{ where} \quad (5)$$

$$\Delta \ln Y_{it} = \ln Y_{it} - \ln Y_{it-1}$$

where $i = 1$ for Hog price, 2 for wholesale Pork price, and 3 for wholesale Beef price. The order of p in expression (5) for hog, wholesale pork, and wholesale beef prices is 1, 5, and 5 respectively.

The Ljung-Box Q test statistic for serial correlation of the error term in (5) follows a χ^2_q distribution, where q is degrees of freedom, in this case the number of lags.

$$Q = N(N+2) \cdot \sum_{k=1}^q \frac{\hat{\rho}_k^2}{N-k} \text{SIM} \chi^2_q \quad (6)$$

$$\hat{\rho}_k^2 = \frac{\sum_{t=k+1}^N (\varepsilon_t^2 - \hat{\sigma}^2)(\varepsilon_{t-k}^2 - \hat{\sigma}^2)}{\sum_{t=1}^N (\varepsilon_t^2 - \hat{\sigma}^2)^2}, \quad \hat{\sigma}^2 = \frac{1}{N} \sum_{t=1}^N \varepsilon_t^2 \quad (7)$$

Engle's LM test to diagnose the price series for autoregressive conditional heteroskedasticity (ARCH) is expressed as

$$LM(q) = W' Z (Z' Z)^{-1} Z' W \quad (8)$$

which is distributed as χ^2_q , where q , the number of restrictions, is the degrees of freedom, and where

$$W = \left(\frac{\hat{\varepsilon}_1^2}{\hat{\sigma}^2}, \dots, \frac{\hat{\varepsilon}_1^2}{\hat{\sigma}^2} \right)', \quad Z = \begin{pmatrix} 1 & \hat{\varepsilon}_0^2 & \dots & \hat{\varepsilon}_{-q+1}^2 \\ 1 & \hat{\varepsilon}_1^2 & \dots & \hat{\varepsilon}_{-q+2}^2 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & \hat{\varepsilon}_{N-1}^2 & \dots & \hat{\varepsilon}_{-q+N}^2 \end{pmatrix}$$

where $\hat{\sigma}^2$ is the variance of $\hat{\varepsilon}$, and $\hat{\varepsilon}'$ is the error of (5).

The results of the Q and LM tests (Table 4) shows that there is a no serial correlation, but that ARCH exists.

Table 5. Results of Tests for Autocorrelation (Q) and ARCH (LM)

Lag	Beef wholesale price		Hog price		Pork wholesale price	
	Q stat.	LM stat.	Q stat.	LM stat.	Q stat.	LM stat.
3	217.8601	237.6611	41.3053	37.2803	297.7801	412.5675
6	238.4084	243.5692	54.6378	43.3539	297.8093	430.9893
9	248.7628	246.8747	79.0746	62.3684	297.8782	432.6147
12	254.8656	249.7627	79.4321	63.2489	298.5723	433.9072

Thus, the GARCH(p,q) intervention model with AR(r) can be written as

$$\Delta \ln Y_t = \alpha_0 + \alpha_1 \cdot \Delta \ln Y_{t-1} + \alpha_2 \cdot \Delta \ln Y_{t-2} + \dots + \alpha_r \cdot \Delta \ln Y_{t-r} + \beta_1 \Delta C_t + \beta_2 \Delta D_t + \varepsilon_t \quad (9)$$

$$\Delta \ln Y_t = \ln Y_t - \ln Y_{t-1}, \quad \Delta C_t = C_t - C_{t-1}, \quad \varepsilon_t = v_t \sqrt{h_t}, \quad h_t = \omega + \sum_{i=1}^p \gamma_i \cdot h_{t-i} + \sum_{j=1}^q \delta_j \cdot \varepsilon_{t-j}^2$$

where $Y_t = (Y_{t1} Y_{t2} Y_{t3})'$, $\alpha_r = (\alpha_{r1} \alpha_{r2} \alpha_{r3})'$, $\varepsilon_t = (\varepsilon_{t1} \varepsilon_{t2} \varepsilon_{t3})'$, with 1 representing hog prices, 2 representing wholesale pork prices, and 3 representing wholesale beef prices.

The dummy variables reflecting the U shape of the first and second shocks caused by FMD are included in (10) as shown in Figures 2 and 3.

$$\begin{aligned} v_t &= (v_{t1} v_{t2} v_{t3})', \quad h_t = (h_{t1} h_{t2} h_{t3})', \quad \omega = (\omega_1 \omega_2 \omega_3)' \\ \beta_i &= (\beta_{i1} \beta_{i2})', \quad \gamma_i = (\gamma_{j1} \gamma_{j2} \gamma_{j3})', \quad \delta_j = (\delta_{j1} \delta_{j2} \delta_{j3})' \\ C_t &= (C_{t1} C_{t2} C_{t3})': 1^{\text{st}} \text{ FMD Dummy,} \\ C_{ti} &= \left(0, \dots, \left(\frac{1-20.5}{40} \right)^2, \dots, \left(\frac{20-20.5}{40} \right)^2, 0, \left(\frac{21-20.5}{40} \right)^2, \dots, \left(\frac{40-20.5}{40} \right)^2, \dots, 0 \right) \\ D_t &= (D_{t1} D_{t2} D_{t3})': 2^{\text{nd}} \text{ FMD Dummy,} \\ D_{tj} &= \left(0, \dots, \left(\frac{1-24}{57} \right)^2, \dots, \left(\frac{23-24}{57} \right)^2, 0, \left(\frac{25-24}{57} \right)^2, \dots, \left(\frac{57-24}{57} \right)^2, \dots, 0 \right) \end{aligned}$$

Table 6. Estimation Results of GARCH model

Hog Price		Wholesale Pork Price		Wholesale Beef Price	
Parameter	Coeff	Parameter	Coeff	parameter	Coeff
α_{01}	0.000325 (0.98)	α_{02}	0.000829 (0.79)	α_{03}	0.000415 (0.78)
α_{11}	-0.0462** (-2.55)	α_{12}	0.3022** (7.51)	α_{013}	0.3333** (10.99)
α_{21}		α_{22}	0.2016** (5.89)	α_{23}	0.1569** (4.69)
α_{31}		α_{32}	0.1737** (6.15)	α_{33}	0.0923** (3.43)
β_{11}	-0.3244** (-23.58)	β_{12}	-0.1929** (-5.45)	β_{13}	-0.0338 (-1.15)
β_{21}	-0.0718** (-7.33)	β_{22}	0.000375 (0.01)	β_{23}	-0.002107 (-0.05)
ω_1	0.000137** (28.93)	ω_2	0.001685** (4.71)	ω_3	0.0000714** (5.66)
γ_{11}	0.5140** (13.97)	γ_{12}	0.1436** (3.57)	γ_{13}	0.1658** (10.13)
γ_{21}		γ_{22}		γ_{23}	
δ_{11}		δ_{12}	0.2746* (1.86)	δ_{13}	0.8029** (47.12)

():t-value, * : 10% significance level ** : 5% significance level

Discussion of Results

Two models used to measure the persistence of price behavior, Box & Tiao's SIM and a supplementary GARCH model, are estimated to analyze the impacts on hog, wholesale pork, and wholesale beef prices of two FMD outbreaks in Korea. Both models indicate that the FMD outbreak in 2000 affected prices more than the FMD outbreak in 2002. The biggest effect was on hog prices, followed by wholesale pork and then by wholesale beef. However, the two models differ in their characterization of the effects.

Figures 6 and 7 illustrate the results for hog prices. As Figure 6 indicates, both models show that hog prices decreased significantly immediately after the outbreak. The models differ in that the SIM model results suggest a prolonged decrease in prices, along with initially higher volatility, while the GARCH model results suggest a rebound in prices, then another decline, in an inverted trough shape. This shape reflects constraints on the GARCH process.

Figure 7 indicates, though, that after the second outbreak in 2002, hog prices decreased initially only by about 1/10 of the amount that prices decreased after the first outbreak. As in Figure 6, the SIM results suggest a prolonged decrease in prices, while the GARCH results suggest that prices followed an inverted trough shape, as with the first outbreak.

After the first outbreak prices dropped by about 20% initially until the government intervened with its purchase program. Prices gradually returned to normal over a 30-day period. However, the second outbreak caused a much smaller decrease than the first outbreak, and its persistence was much shorter. Apparently, although producers engaged in "panic selling" after the first outbreak, the precedent that the government set by its purchase program intervention after the first outbreak kept the markets more stable during the second outbreak. Producers did not sell prematurely after the second outbreak as they had after the first outbreak. Figures 8 through 11 reflect the results for pork and beef prices in the first and second outbreaks.

An implication of this work for similar events in the future, including bioterrorism events, is that government agencies can significantly reduce economic loss and market disruption by clearly establishing their willingness to intervene in the markets. A second implication is that the GARCH and the Box-Tiao SIM models reflect different aspects of market response to an intervention. Both models show nearly the same initial response to a market shock. But while the GARCH model reflects a decaying response as the market gradually adjusts, the Box-Tiao SIM model is not as constrained functionally, and captures more of the volatility in prices resulting from the market shock.

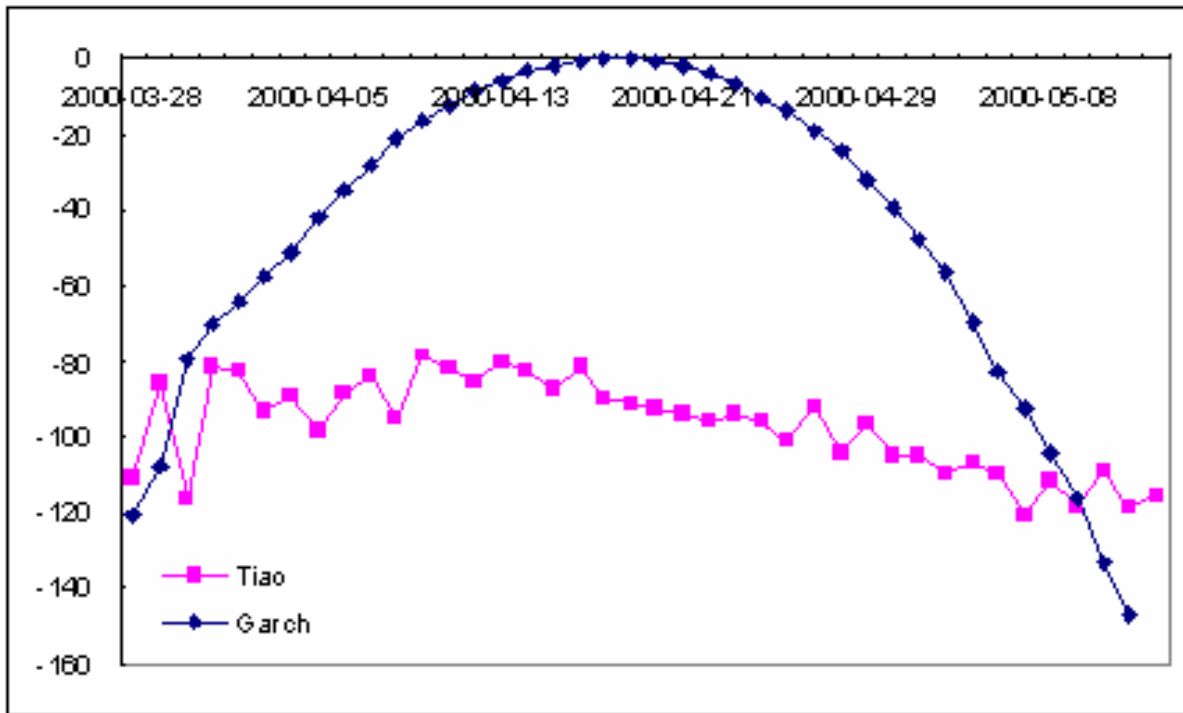


Figure 6. Impact of 2000 FMD Outbreak on Hog Prices

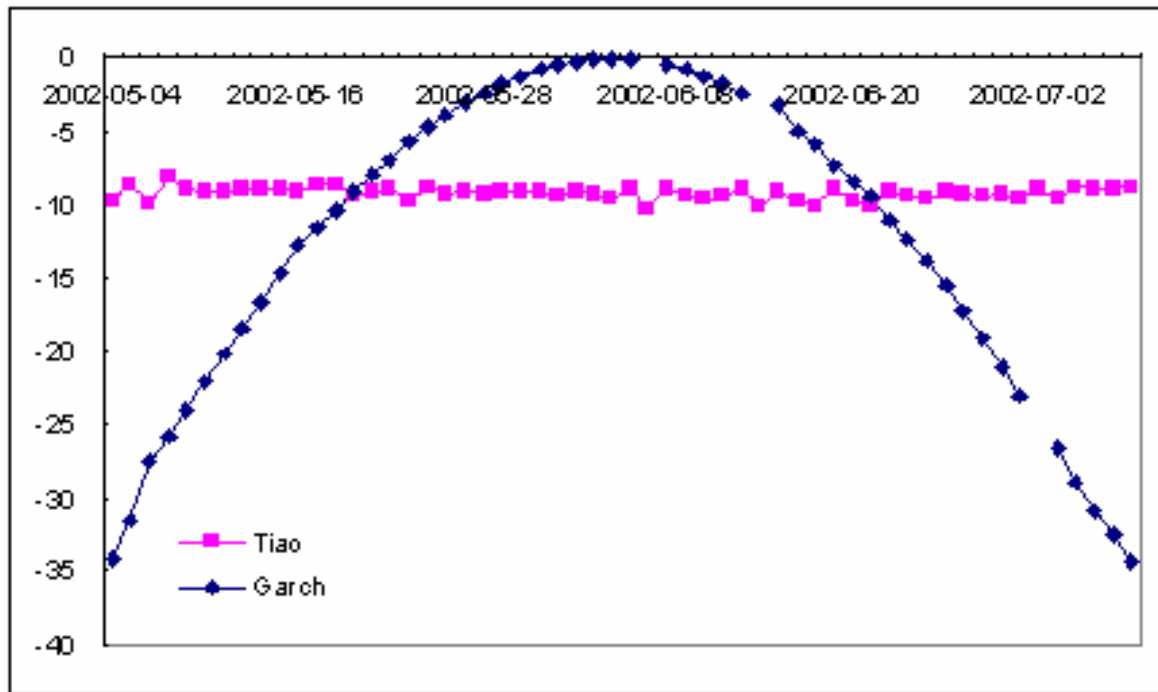


Figure 7. Impact of 2002 FMD Outbreak on Hog Prices

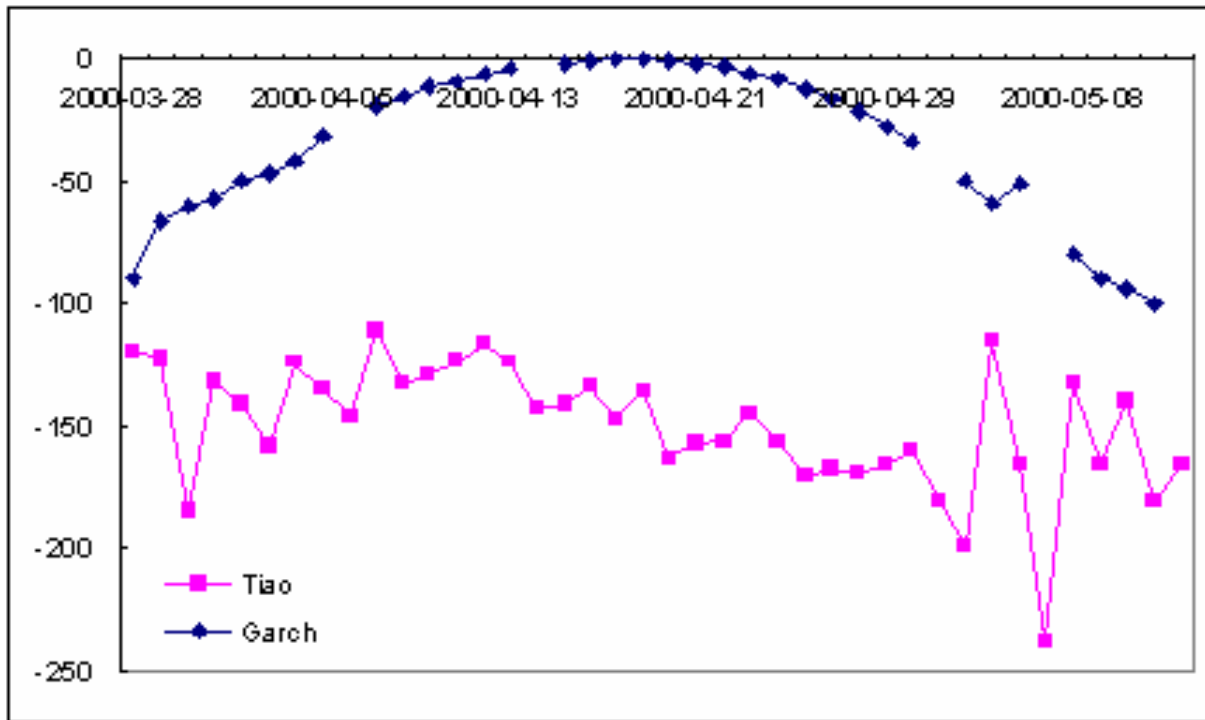


Figure 8. Impact of 2000 FMD Outbreak on Wholesale Pork Prices

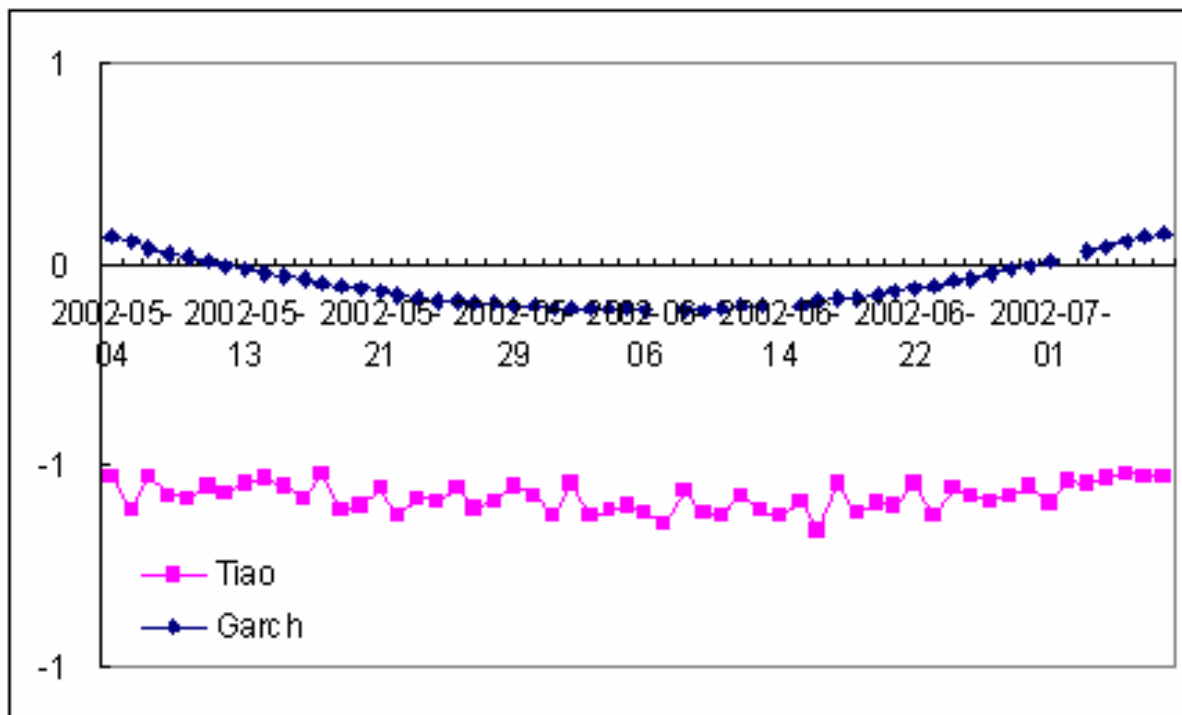


Figure 9. Impact of 2002 FMD Outbreak on Wholesale Pork Prices

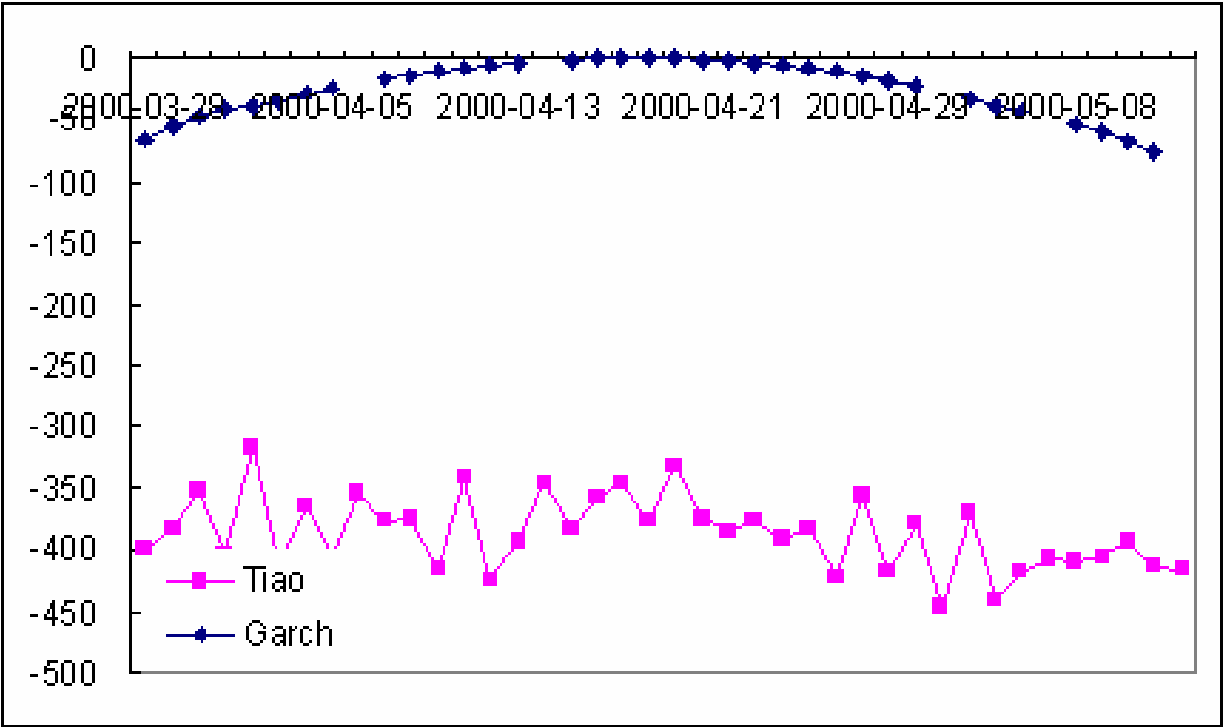


Figure 10. Impact of 2000 FMD Outbreak on Wholesale Beef Prices

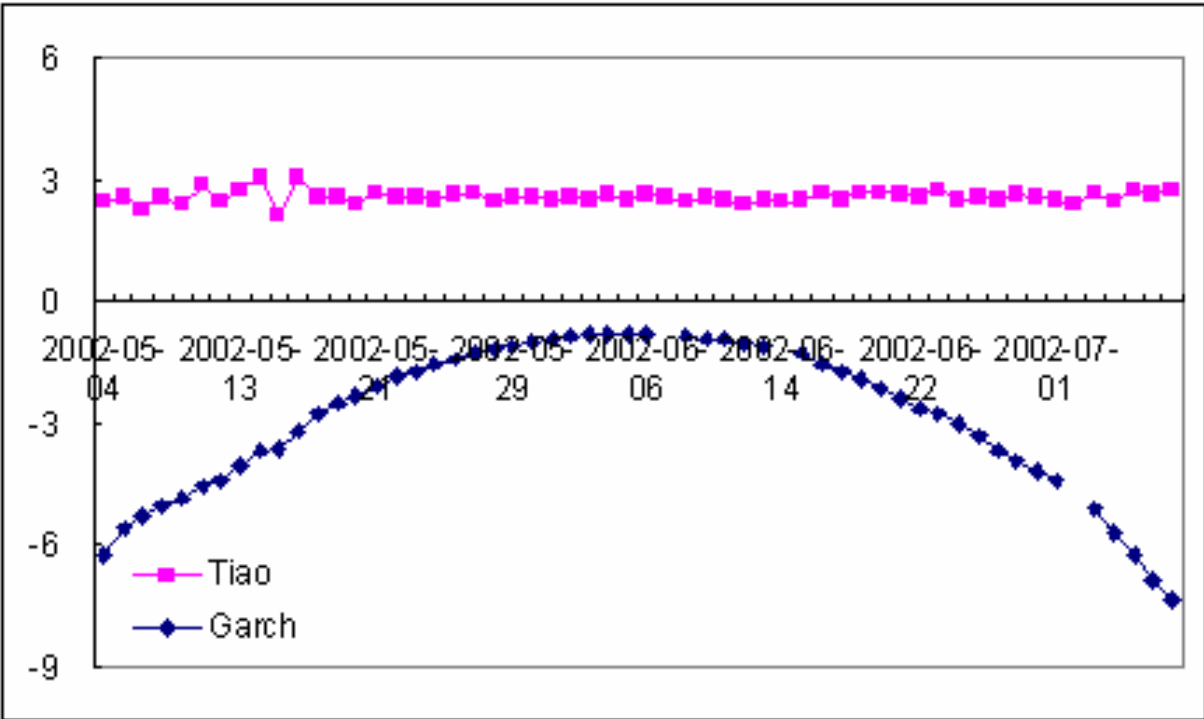


Figure 11. Impact of 2002 FMD Outbreak on Wholesale Beef Prices

References

Aulaqi, N.A. and W.B. Sundquist. "A Benefit-Cost Analysis of Foot-and-Mouth Disease Spread and Control in the United States," A Study of the Potential Economic Impact of

Foot-and-Mouth Disease in the United States. E.H. McCauley et al. (eds.) Staff Paper TB-1597. St. Paul, MN: University of Minnesota, May 1979. Pp. 71-102.

Blake, A., M.T. Sinclair, and G. Sugiyarto. "The Economy-Wide Effects of Foot and Mouth Disease in the UK Economy", Cristel DeHaan Tourism and Travel Institute, Nottingham Business School, 2002. <http://www.nottingham.ac.uk/ttri/>

Bollerslev, T. "Generalized Autoregressive Conditional Heteroskedasticity", *Journal of Econometrics*, 31, 1986.

Box, G.E.P. and Tiao, G.C., "Intervention analysis with applications to economic and environmental problems." *Journal of American Statistical Association*, 70, 1975.

Ekboir, Javier M. "Potential Impact of Foot and Mouth Disease in California: The Role and Contribution of Animal Health Surveillance and Monitoring Services." Agricultural Issues Center, Division of Agriculture and Natural Resources, University of California, 1999. <http://aic.ucdavis.edu/pub/fmd.html>. Accessed January 15, 2006.

Engle, R.F. "Autoregressive conditional heteroskedasticity with estimates of the variance of U.K inflation", *Econometrica*, 50, 1982.

Fuller, F., J.F. Fabiosa, and V. Premakur, "World Impacts of Foot and Mouth Disease in Taiwan," CARD Briefing Paper 97-BP-16.

Paarlberg, P.L., J.G. Lee, and A.H. Seitzinger. "Measuring Welfare Effects of an FMD Outbreak in the United States," *Journal of Agricultural and Applied Economics*. 35,1(April 2003):53-65.

Paarlberg, Philip L. John G. Lee, and Ann H. Seitzinger. "Economic Modeling of Livestock Disease Outbreaks" *International Food and Agribusiness Management Review*, Volume 8, Issue 1, 2005.

Petry, M., P.L. Paarlberg, and J.G. Lee. "PRRS and the North American Swine Trade: A Trade Barrier Analysis," *Journal of Agricultural and Applied Economics*. 31,3(December 1999):425-436.